New field pea selections for Coastal Algeria

CONTEXT

Conservation Agriculture in particular, and sustainable agriculture in general, are not compatible with the extensive monoculture and the repeated cropping of wheat that are widespread in rainfed areas of the Mediterranean region. **Including legumes in crop rotations** would be particularly valuable because greater cultivation and utilization of these crops can contribute to climate change mitigation, lower energy consumption, increased soil fertility, more resilient cropping systems, greater feed and food security, and healthier food and living environments (Figure 1). **These crops, however, are little cultivated in Europe and North Africa** because of their wide profitability gap relative to wheat and other major cereals, which profited from much greater crop improvement research and usually greater supporting measures than legumes. This is why **legume yield improvement was one of the objectives of the project CAMA.**

CAMA identified field pea as a major target of its plant breeding effort because this crop is:

(1) widely adapted to soil, climate and management conditions of the Mediterranean region, and fairly drought tolerant (because of its winter-spring cycle and early maturity);

(2) well-known by farmers of the Mediterranean region;

(3) flexible and diversified for crop use (feed or food grain; fodder; protein concentrates and isolates);

(4) more competitive against weeds than other grain legumes;

(5) not targeted by the international research centre ICARDA with a Mediterranean mandate, and promising based on prior knowledge and available germplasm and genomic resources (also thanks to earlier projects, e.g., Reforma).

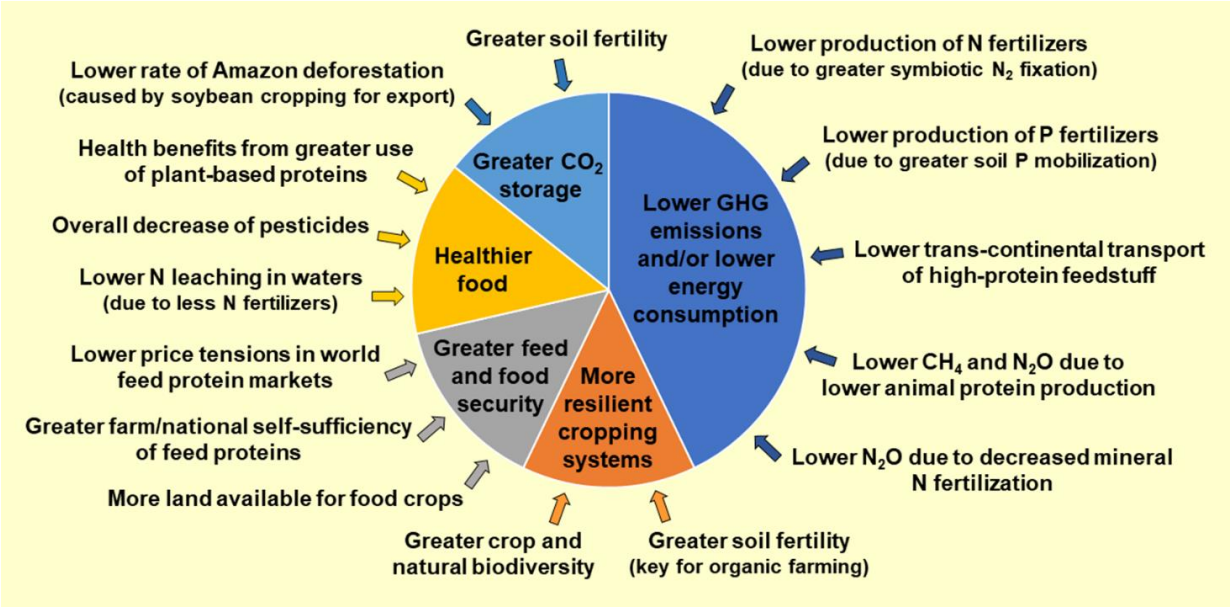

Fig. 1. Advantages associated with greater cultivation and utilization of legume crops

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Aims: One aim of this research was to produce new cultivars with higher grain yields for Algeria, Morocco and Italy. A second aim was comparing the ordinary phenotypic selection of inbred lines with two innovative selection methods: a biotechnology-based one, i.e., the genomic selection of inbred lines (which could reduce the cost and the time needed for variety selection), and an agroecology-based one, i.e., the selection of evolutionary populations (which are genetically heterogeneous, unlike the inbred lines, and are characterized by very low selection cost)

WORK DONE IN CAMA

CAMA has developed **pea improvement** research for various **climatically diverse Mediterranean regions**. **Coastal Algeria exhibits moderate drought** conditions characterized by substantial annual rainfall variability. It is noteworthy that a significant rupture occurred in 1990, leading to a discernible trend of declining rainfall. This trend is evidenced by an average inter-annual reduction from 731.25 mm (1968-1990) to 594.13 mm (1991-2022), representing a notable 19% decrease (unpublished data, PNR-2021 project). Moreover, this region experiences considerable intra-annual variability in rainfall, underscoring the importance of considering data from multiple years for effective plant selection. Notably, the years 2021-2022 and 2022-2023 exhibited substantial variation, as depicted in Figure 2 below.

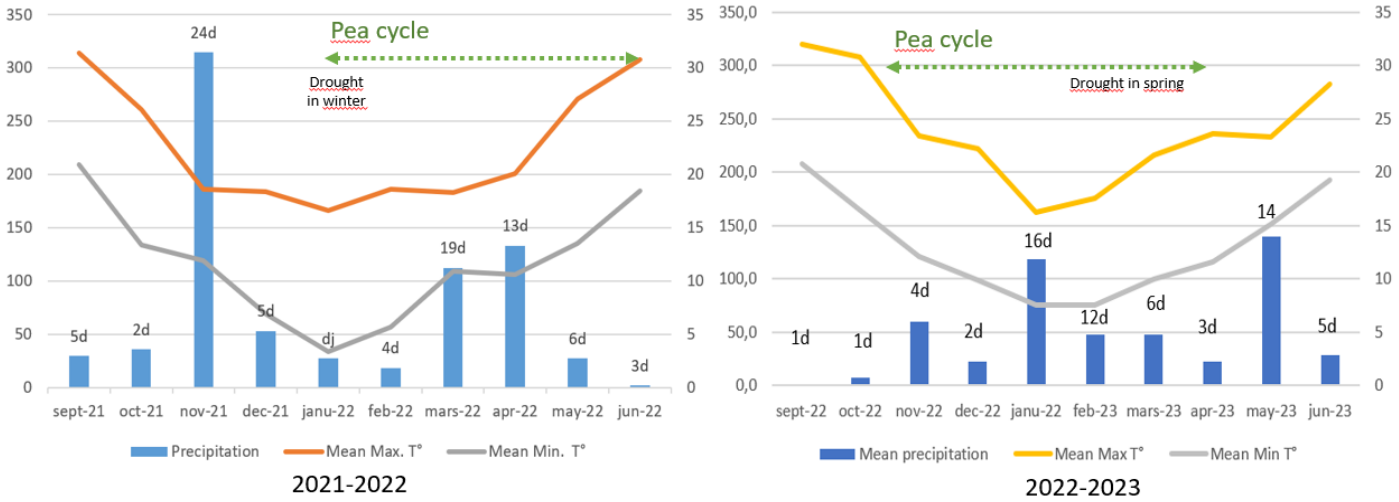

Fig.2. Intra-annual variation of climate in Coastal Algeria

CAMA Conservation Agriculture in the Mediterranean Area

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The inbred lines utilized for phenotypic selection (PS), establishment and implementation of genotypic selection (GS), and the development of evolutionary populations were derived from controlled crosses between 3 commercial cultivars: Attika (a European spring-type cultivar), Isard (a French winter-type cultivar), and Kaspa (an Australian cultivar), chosen for their high and consistent grain yield, similar duration of growth cycle, and diverse positive traits. Out of 288 inbred lines evaluated for grain yield in coastal Algeria (Algiers), three lines were phenotypically selected (one line per cross) within the ArimNet project REFORMA (as documented in Annicchiarico et al., 2020, Int. J. Mol. Sci. 21:2414) and following work. Some 200 lines from each of these crosses underwent genotyping using several thousand SNP markers obtained via ApeKI-based genotyping-by-sequencing (GBS). The GS model tailored for coastal Algeria, based on data from Algiers, selected 6 lines (2 lines per cross). The evolutionary population predominantly evolved under natural selection, initially over three years in Coastal Algeria. The 10 selections were field-evaluated in both pure and mixed stand experiments under autumn sowing conditions in Coastal Algeria (Algiers) over two cropping years 2021-22 and 2022-23 (Figure 3).

Fig. 3. Left: Pure stand in field. Right: Mixe stand in field in 2021-22 and 2022-23

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RESULTS

Results for **grain yield and other traits In costal Algeria (Algiers)** of a subset of well-performing inbred lines and the evolutionary population bred for this region and the three elite parent cultivars are reported in Table 1. The table reports the LSD value for each trait, which indicates the threshold of difference beyond which the values of two materials are statistically different with **a probability of error ≤ 5%.**

The line KI_S125, selected genomically, displayed a clear grain yield advantage over any other material (Table 1). This line out-yielded also the top-yielding **cultivar Attika**, relative to which it showed a yield advantage of 10%. Compared to the locally most-grown cultivar Aviron, the line KI_S125 presented a 60% yield advantage and a 37% straw yield advantage. The **moderately high straw production** of this line is also of interest, given the fairly high forage value of the pea straw for ruminant feeding.

The **grain yield of the evolutionary population selected for Algeria was somewhat** lower than that of the average of the inbred lines selected for Algeria (2.802 vs. 3.048 t/ha), but **showed a high yield stability** in unfavourable years and moderately high straw production.

The lines selected for Algeria exhibited a remarkable variation in straw yield and onset of flowering (with a trend for earlier material towards relatively better performance in the drier year).

Table 1. Grain yield and other traits assessed in a two-year field evaluation in Coastal Algeria, for inbred lines issued by phenotypic selection (PS) or genomic selection (GS), one evolutionary population and three elite parent cultivars of the selected material

Material	Grain yield (t/ha)	Onset of flowering (dd)	Plant height (cm)	Seed weight (g)	Straw yield (t/ha)
Inbred line selections					
KI_S125 (GS)	**4.101**	**28.8**	61.7	0.156	6..426
KA_156 (PS)	3.316	40.7	86.5	0.158	**7..363**
AI_S6 (PS)	3.232	28.3	68.0	0.166	5..061
KA_S106 (GS)	3.071	34.5	67.5	0.158	5..820
KI_S8 (PS)	2.975	**26.8**	64.3	0.153	**7..900**
KI_S78 (GS)	2.958	41.7	74.7	0.149	5..972
KA_L250 (GS)	2.710	42.7	68.3	0.147	6..133
AI_S118 (GS)	2.591	27.5	58.7	**0.183**	4..773
AI_L15 (GS)	2.476	31.0	64.0	0.135	4..735
1 Evolutionary population					
EP Algeria	2.802	**28.8**	61.8	0.162	6..640
3 Parent cultivars					
Attika	3.726	30.2	61.8	**0.190**	5..841
Isard	3.507	30.2	**43.5**	0.139	4..311
Kaspa	2.637	43.0	**81.5**	0.145	**7..318**
LSD (P < 0.05)	0.659	2.7	8.5	0.139	1..461

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Table 2. Pea grain yield in pure stand, and pea, barley and total yield and pea proportion in mixed stand, for inbred lines issued by phenotypic or genomic selection and one evolutionary population, observed in Alger (Algeria) in the cropping year 2022

Material	Pea yield in pure stand (t/ha)	Pea yield in mixed stand (t/ha)	Barley yield in mixed stand (t/ha)	Total yield in mixed stand (t/ha)	Pea proportion on total yield in mixed stand
KI_S78	1.393	0.764	3.973	**4.738**	0.161
KI_S125	**2.162**	0.430	**3.917**	**4.347**	0.099
EP Algeria	1.735	**1.236**	2.917	**4.153**	**0.298**
KA_156	1.734	**0.950**	2.699	3.649	**0.260**
KA_L250	1.333	0.808	2.584	3.392	0.238
KI_S8	1.713	0.490	2.781	3.271	0.150
AI_L15	1.067	0.255	2.846	3.101	0.082
AI_S6	1.773	0.552	2.542	3.094	0.178
KA_S106	0.930	0.315	2.485	2.800	0.112
AI_S118	1.449	0.292	2.499	2.791	0.105
LSD (P < 0.05)	**0.504**	**0.498**	**1.028**	**1.067**	**0.135**

The evaluation of 10 selections for Algeria under pure stand and mixed stand with barley in 2021-2022 revealed, on average, somewhat g**reater total (barley + pea) grain yield of the mixtures relative to the barley pure stand** (3.533 vs. 3.467 t/ha) along with strong competition exerted on pea, of which the average proportion in the mixture averaged 0.171. Pea yield results are given in Table 2. Remarkably, the **population was the top-yielding pea material in intercropping**, reaching a pea proportion of nearly 30% that allowed for a balanced mixture and producing nearly three-fold as much pea as the top-yielding pea line in pure stand (KI_S125). There was modest consistency of pea genotype yield response across conditions (r = 0.33), with a trend towards relatively better yield and proportion in mixed stand of taller and later-flowering genotypes.

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CONCLUSIONS AND RECOMMENDATIONS

The project CAMA succeeded in **generating a few potential varieties which, for the main Algerian region, represent a clear improvement in terms of grain yield**.

The **lines KI_S125** (genotype selection), which was top-ranking, and the second one **KA_156** (phenotypic selection), are under multiplication, before proposing them for registration in the Algerian Register of Varieties.

The **evolutionary population**, which displayed high yield stability, could be suitable for **cultivation in less favourable conditions**, particularly those featuring highly variable climatic conditions across years (as increasingly occurring due to climate change). Because of its genetic heterogeneity, this material cannot be registered as a commercial variety. However, this population will be proposed for agriculture as farmer-produced seeds spreading through informal seed systems.

CAMA produced also **important scientific information for crop improvement of pea** and other inbred grain legumes. It demonstrated the **value of genomic selection**, which generated inbred lines with agronomic value at least comparable with that of phenotypic selection in a shorter time, and highlighted the adaptability and high yield stability of an **innovative and low-cost variety type such as the evolutionary population**

Reference

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